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Name: James Neil Ogden   Date of Degree: August 11, 1962

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Scope of Study: This study was concerned with the presentation of an outline for teachers to use in a General Science course to supplement that unit covering the earth sciences.

Findings and Conclusions: Most students become interested in a subject only when their curiosity is aroused. Through the use of rock and mineral specimens it should be very easy to arouse that curiosity, and instill a desire in the youngster to find out more about how they were formed. Field trips constitute a major part of a unit dealing with geology and they must be carefully planned ahead of time. As the youngster collects and identifies, his attention then is directed toward those areas of rock formation, deposition, erosion, and geologic time.

ADVISOR'S APPROVAL. L. Herbert Bruneau.

GEOLOGY FOR THE GENERAL SCIENCES

By

James Neil Ogden

Bachelor of Science

Southeastern State College

Durant, Oklahoma

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GEOLOGY FOR THE GENERAL SCIENCES

Thesis Approved:

L. Herbert Bruneau.
Thesis Adviser

____

____
Dean of the Graduate School

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CHAPTER I

Introduction

Nothing is as important in the natural world as our own earth and the rocks beneath our feet. In this report an attempt is made to prepare a unit of the study of earth science which will be applicable to that unit dealing with geology in a General Science text.

At the beginning of this research it was difficult to decide where to start, but after collecting material it seems hard to find a place to stop.

Most students are deeply impressed with the collection of minerals and rocks, so this seems a likely place to start. If an interest is created it will then be an easy task to work into theories on the formation of the earth, erosion, and the geologic time table.

The procedure followed in this report is not meant to be a course in geology, but rather a six weeks unit in theory and laboratory technique taught ninth grade students to supplement what is usually a very weak unit in most General Science texts.

This report will teach the student how to recognize the common rocks and minerals, how to identify them and, it is hoped, will create a continuing interest in the Earth Sciences.

The beauties of nature are exhibited by the features of the earth, therefore, an attempt must be made to reveal what those features are and how they came to be.

CHAPTER II

Minerals

Collectors of minerals and rocks are rapidly becoming more numerous all over the world, especially in the United States and Canada.

The equipment necessary for a collecting trip should consist of a geologists pick or a hammer and chisel, a knapsack for carrying the specimens, field notebook and wrapping paper for a record, pocket magnifier, a bottle of dilute hydrochloric acid for testing calcareous materials, and hiking shoes, preferably with rubber soles.

Man-made exposures of rocks and minerals are commonly the best source of specimens. Railroad or highway cuts, rock quarries, dump piles and mines offer reasonably good exposures.

The earth is a ball of rock materials approximately 8,000 miles in diameter and weighing about six sextrillion tons. It is made up of a thick heavy core and several concentric layers. The continents consist principally of granite rock floating above heavier rock layers. In the study of rocks and minerals, interest is usually concentrated in the earth's crust which is from 10 to 30 miles in depth.

Minerals are composed of discrete substances, called elements, which are composed of smaller particles called atoms and molecules. It becomes necessary to know the composition of these minerals to understand the rocks that compose most of the earth's crust.

A mineral is a naturally occuring substance with a characteristic internal structure determined by a regular arrangement of the atoms or ions within it, and with a chemical composition and physical properties that are either fixed or which vary within a definite range. Minerals, then, are natural substances, found ready-made out-of-doors. Synthetic products made in a laboratory are not minerals.

To say that minerals have definite chemical and physical properties, or properties that vary within certain definitely fixed limits, is merely to point out that all particles of a single kind of mineral are alike in their physical and chemical characters regardless of the parts of the world in which they are found.

Every atom has a small, dense nucleus that contains one or more protons, and, except in the simplest atom, that of hydrogen, one or more neutrons. The nucleus holds over 99.9 per cent of the mass of an atom but only about one-billionth of its volume, so the outer parts of atoms are mostly space.

An element is a substance that consists of atoms of only one kind, which is just another way of saying that the nucleus of each of the atoms in any particular element must have exactly the same electrical charge. Atoms behave chemically as though their electrons rotate about the nucleus in concentric shells. Hydrogen, the simplest element, consists of one proton around which an electron revolves. The more complex the atom, the larger the nucleus and thus the inner electron shell is retained, but additional electrons lie in one or more shells farther out. The chemical characteristics of an element seem to depend entirely on the number of positive electric charges-and thus on the number of protons-in its nucleus. This number is the atomic number of the element.

For some reason, those elements are chemically the most stable whose outermost electron shell contains eight electrons. Atoms having fewer than eight electrons in the outer shell do combine with others. Each element is constantly striving to obtain eight electrons in its outer shell and accomplishes this in three ways.

1. An atom may lose an electron becoming positively charged, or a cation.
2. An atom may gain an electron becoming negatively charged, or an anion.
3. An atom may share electrons with another element.

Those elements composing most of the earths crust are, oxygen and silicon. Of the common elements in the earths crust principally oxygen gains electrons and principally silicon has a tendency to share, therefore most rocks and minerals must get their electrons from the oxygen and will be oxides. A rock or mineral rich in oxygen and silicon is called a silicate; most of the rocks in the earths crust, therefore, are silicates.

The difference between a rock and a mineral should be clearly understood. Rocks are essential building materials of which the earth is constructed, whereas minerals are substances contained in rocks. Most rocks contain more than one mineral.

The following chart shows some common mineral groups, their chemical formulae and mineral name.

MINERAL GROUP	CHEMICAL FORMULA	MINERAL NAME
Carbonate	$CaCO_3$	Calcite or Limestone
Oxide	Fe_2O_3	Hematite
Sulfide	PbS	Galena
Sulfate	$CaSO_4 \cdot 2H_2O$	Gypsum

Some of the native elements in the earths crust are platinum, gold, silver, carbon, copper, and sulfur. Some of the more common minerals are; beryl, tourmaline, carmatite, garnet, apatite, fluorite, halite.

The properties of minerals are;

1. Naturally occurring.
2. Regular periodic internal structure.
3. A fixed chemical composition.

Each mineral has a unique set of physical properties by which it can be identified and some of these properties are;

1. Luster-the manner in which the surface of the mineral reflects light. Luster may be

either metallic or non-metallic.

2. Hardness- the resistance of the surface to scratching Ten key minerals in ascending order of resistance to scratching are:

1. Talc
2. Selenite
3. Calcite
4. Fluorite
5. Apatite
6. Feldspar
7. Quartz
8. Topaz
9. Corundum
10. Diamond

3. Fracture- break not along a plane.

4. Cleavage- break along a plane.

5. Streak- color of the pwdered form of the mineral.

6. Specific gravity

7. Color

The following chart will show how some common minerals are classified according to the properties listed above.

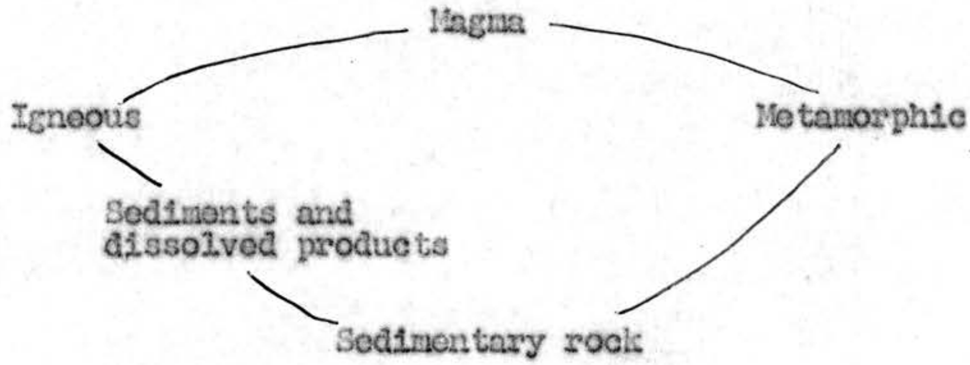
MINERAL	LUSTER	HARDNESS	FRACTURE
Galena	Metallic	will not scratch with a fingernail	3 perfect planes
Pyrite	metallic	will not scratch with a knife	no cleavage
Gypsum	dull	will scratch with a fingernail	2 perfect planes
Calcite	vitreous to pearly	will scratch with a knife	rhombohedral
Quartz	vitreous	will not scratch with a file	none
Beryl	sub-vitreous	will not scratch with knife or file	none
Tourmaline	vitreous	will not scratch with a file	none
Garnet	sub-vitreous	will not scratch with a file	none

Some minerals which are considered gemstones are diamonds, opal, emerald, onyx, amethyst, agate, jasper and jade. "That a gemstone should be a delight to the eye is a truism that need not be laboured." (Smith, 1958).

CHAPTER III

Rocks

Below is a chart showing a cycle in the formation of three different classes of rocks.



The three principle classes of rocks are;

1. Igneous rocks-rocks formed from molten material beneath the surface of the earth.

2. Metamorphic rocks-rocks formed from pre-existing rocks as a result of heat, pressure, chemical means, and geologic time.

3. Sedimentary rocks-rocks which are formed from weathered debris of pre-existing rock, or by chemical and bio-chemical processes.

Igneous rocks are formed from melted rock beneath the earth's surface. Molten rock material beneath the surface of the earth is called magma. Magma consists primarily of silicates plus other elements in solution. The origin of igneous rock is magma which solidifies upon cooling to form solid, crystalline material. Crystallization of magma takes place shortly after passing the melting point, if slow cooling takes place far beneath the surface the resulting rock is plutonic whereas rapid cooling at or near the surface results in finer grained glass rocks. (Rogers, 1921).

The texture of igneous rock is defined by the ease with which its crystals are seen. If a hand lens is not needed we call it phaneritic, if the crystals are too small to be seen with the naked eye it is said to be aphanitic, and if no crystals are formed it is glass.

One of the most common igneous rocks is glass, which is formed by rapid cooling of melted silicates. The following figure shows some igneous rocks you will be expected to know. These rocks are classified according to their mineral content.

IGNEOUS ROCKS	MINERAL CONTENT
Granite	Quartz and feldspar
Biotite granite	Aluminum silicate
Muscovite granite	Aluminum silicate of potassium
Pegmatite	Feldspar and mica
Gabbro	Pyroxene and feldspar

Sedimentary rocks are the products of weathered materials transported and deposited as sediments. They are formed from pre-existing rock materials.

Sedimentary rocks are formed by;

1. Lithification-or solidification by the cementation of calcite or silica and iron materials.
2. Compaction-by compression into small grained clay.
3. Recrystallization-in which small crystals are allowed to stand and recrystallize into larger crystals.

The most common examples of sedimentary rocks are sandstone, shale, and limestone, the last formed from the precipitation of calcium carbonate.

Sedimentary rocks are classed as clastic or non-clastic according to whether or not they are composed of broken fragments. The most important aspects of clastic texture are grain size and grain shape. Coarse clastic rocks are conglomerates if the fragments are round, breccia if the fragments are angular.

Rock fragments are given names which vary according to size of the fragments. If a fragment is;

1. more than 2mm in diameter it is called gravel.
2. less than 2 mm but more than 1/16 mm in diameter it is sand.
3. 1/16 mm in diameter or less it is silt.
4. less than 1/256 mm in diameter it is clay. (Rogers, 1921).

Clastic rock consisting principally of sand sized particles are called sandstones. Shale consists of particles of less than 1/256 mm in diameter.

Metamorphic rocks have been changed in form or mineral composition due to a change in environment, this does not include melting. Temperature, however, is very important to the rate at which metamorphism takes place. The agents of metamorphism are;

1. Temperature which is determined by,
   a. uplift which reduces temperature.
   b. burial which increases temperature.

2. Recrystallization caused primarily by pressure.

3. Replacement of minerals by other minerals.

The kinds of metamorphism and the rocks formed are,

1. Thermal-caused by heat where recrystallization takes place and forms marble and quartz.

2. Dynamothermal-caused by heat and direction of pressure. Rocks tend to break along a parallel plane which is foliation. Mud or shale with directed pressure changes to slate.

CHAPTER IV

Economic Minerals

A short unit should be given to the economic minerals because they are second in importance to agriculture. Of the economic minerals, 75% are fuels such as petroleum, gas, and coal; 15% are non-metallic as sulfur and clay; 10% are metallic such as gold, lead, silver, manganese, and copper. Mineral deposits are scattered unevenly all over the world.

Coal which was formed from, primarily, pre-existing plant life, has many uses, the principal one being a fuel. Many other useful substances such as flavor, antiseptics, plastics, analine dye, and perfume and by-products of coal. The formation of coal occurs in 3 principal stages;

1. Peat
2. Lignite
3. Bituminous $\xrightarrow{\text{heat}}$ Anthracite

The origin of peat is in swampy regions of poor drainage and cold temperatures. Living plants grade downward, become packed where there is no air, and become a soggy mass of plant matter. A gelatinous material forms, water is squeezed out, and peat, a poor grade of coal, is formed.

Lignite or brown coal, ignites readily, and is a poor grade of coal.

Bituminous coal has a black color, concoidal fracture, and is called soft coal. Bituminous coal gives good heat but a lot of smoke. Metamorphism, due to heat and pressure in the absence of moisture, gives almost pure carbon content having high heat potential and burning with little smoke. This product is anthracite coal. If anthracite coal is metamorphosed graphite is formed.

The carbon cycle is;

1. Peat-practically no carbon.
2. Lignite-less than 50% carbon.
3. Bituminous-50% to 65% carbon.
4. Anthracite-over 65% carbon.

Metals are deposited in the earth combined with other substances and if the deposits are rich enough to be exploited commercially they are called ores. Mining in early times was based on the fact that the metals, being heavier than water, could be sifted from a running stream. This process is called placer mining and the worthless material is called gangue.

Strategic minerals are those we need but which are commonly in short supply such as nickel, copper, tin, chromite, and aluminum.

Petroleum geology is one of the most important phases of geology. Oil was formed during pre-historic time primarily from animal life. The leading regions of the world in oil production are;

1. Middle East-Saudi Arabia, Kuwait, Iran, Iraq.
2. North Africa-Egypt, Libya, Tunisia, Algiers.
3. Gulf Coast-Texas, Cuba, Venzuela.
4. Caspian Sea-Baku, Russia.
5. Far East-Sumatra, Borneo, Burma.
6. Canada and Central United States. (Moore, 1961).

Of the above Kuwait has 25% of the world supply. It is believed by geologists that oil was formed in the following cycle.

Organic matter

Catalyst

Temperature, pressure

Bacteria

Marine environment

Radio activity ?

Time element

The above cycle is explained;

1. Deposition of organic material in shallow marine waters.
2. Rapid burial to prevent destruction of organic material by bottom dwellers.
3. Normal decomposition with the start of bacterial action.
4. Cessation of bacterial action when the mixture becomes too acid for the bacteria to live.
5. Transformation of residue to hydrocarbons as sediment.

CHAPTER V

Weathering and Other Agents of Erosion

Erosion is the moving about of material whereas weathering is defined as the response of surface or sub-surface rock to contact with wind, water, and atmosphere. It might be stated that weathering is the decay of rock in place.

The principal agents of weathering are classified into two large groups, mechanical and chemical, of which there are many sub-divisions.

I. Mechanical weathering which changes rock to smaller rock.

1. Expansion and contraction due to heat.
   a. Temperature changes.
   b. Lightning
   c. Forest fires

2. Frost action in which water gets into the cracks of rock, freezes thus causing the rock to slide down the hill.
   a. Mass wasting where a large outcropping of rock moves downhill. Many times you have seen what you might consider a rock slide at the foot of a mountain. This is called talus.

3. Miscellaneous types.
   a. Plant roots.
   b. Ants, worms, rodents.
   c. Man. May we note here again that the greatest natural enemy of, even the earth, is man.

II. Chemical weathering is any process or reaction that dissolves or alters the composition of rock.

1. Solution by which the calcium oxide dissolves out of limestone, also carbon dioxide will dissolve to form carbonic acid.

2. Hydration which is the chemical addition of water. Bentonite or shale, will swell upon the addition of water and thus become changed.

3. Oxidation, where oxygen combines with other elements to form oxides. One of the more common ones we see in our area is limonite which results from oxygen being added to pyrite.

4. Carbonation, which is the presence of carbon dioxide.

There are many factors which aid weathering and they may be listed as,

1. Climate.
2. Presence of plants and animals.
3. Size of the particle which is weathered.
4. Composition of the material. The more soluble the rock, the faster it will dissolve or disintegrate.

The depth to which weathering will take place depends on the material at the surface. In Carlsbad Caverns, which are excavated in limestone, weathering has reached a depth of 700 feet. Brazil has layers of shale which have weathered to a depth of 400 feet.

A very good experiment to show the rate of chemical weathering is to fix some common rocks so that water will drip on them and note the time it takes each to weather. Quartz will weather very slowly whereas feldspar, limestone, dolomite weather rapidly. In this experiment one must keep in mind that climate would have a decided effect on weathering rate. In dry climates rocks weather slowly whereas in warm, moist climates the rate increases rapidly.

When ores are weathered you get new minerals one example is the weathering of iron pyrite.

$$2FeS_2 + 2H_2O + 7O_2 \longrightarrow 2H_2SO_4 + 2FeSO_4$$

In the above equation FeS_2 is a yellowish color whereas the product $FeSO_4$ is green in color.

Differential weathering is a process in which several layers of rock weather at different rates; soft rock weathers first and leaves a feature such as the one shown below.

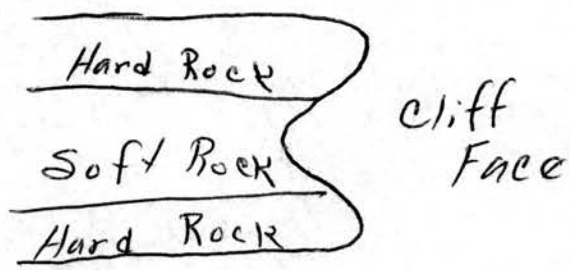


Fig. 1

Another example is the well known "balanced rock" in the Garden of the Gods, Colorado Springs, Colorado. This type of weathering leaves a formation called a "Hoodo".

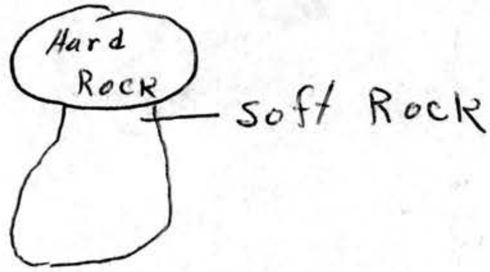


Fig. 2

Up to this point we have discussed only the weathering of rock, and now we take up that phase of erosion more noticeable to us, soil erosion. Soil is defined as a mixture of organic and inorganic material varying in depth, mineral content, and porosity. (Lahee, 1941). Commonly we see loose rock fragments overlying bedrock, this is called regolith. The chief factors of soil formation are;

1. Action of living organisms, principally bacteria.
2. Parent rock material. Igneous rock produces, the best soil because it has more minerals.
3. Time is very important to convert rock into soil.
4. Climate, whether hot, cold, wet, or dry.
5. Slope of the land is a great factor because the more sloping the land, the greater the runoff thus the greater the erosion.

Eroded soil falls into two groups, residual, or soil that has never been moved, and transported soil which was moved by glaciers, wind, water, and rivers. Highly weathered soil is good soil. The chief agents of erosion are wind and water.

Water erosion is of three principal types.

1. Ground water or water beneath the surface.
   a. meteoric which is rain water.
   b. geysers which are principally meteoric.
   c. connate or water that is trapped in sediment.
2. Springs
3. Running water

Each of the types of ground water is influenced by slope and lateral movement.

Most running water is found in rivers; in the United States these rivers move 330 cubic miles of soil per year, one-third of which runs into the Gulf of Mexico by way of the Mississippi River. A permanent stream contains water at all times, except at drought years, and is confined to a channel. Many rivers have branches that fork off from the main channel, these are called tributaries.

There are many things which influence the flow of a stream and its speed. Some are:

1. Gradient-slope of the channel.
2. Volume of water.
3. Amount of load in the stream.

The flat area around a stream is its flood plain, or the area that will be flooded during excessive rainfall.

Rivers are classed as young, mature, or old according to the characteristics they show. The young stream has a V-shaped channel, steep banks, many rapids and cascades, a very narrow bed, clear water and very few tributaries. A mature stream has no waterfalls, its bed is wide and it has a fairly extensive flood plain. The old stream has no cascades, very extensive flood plain and its speed is very slow. There are many Ox-bow lakes due to curves in the original river bed that have been cut off from the main channel.

The competence of a stream is determined by the size of material it can move. Alluvium is stream-transported material and it can vary from silt to boulder size. Below are listed factors that influence the competence of a stream.

1. Velocity of the water.

2. Load.

3. Width of flood-plain.

4. Shape of the channel.

The transportation of its load is the principal function of a stream. Abrasion is the grinding away of the earth's material by the streams load. Speed of the stream is greatly affected as its shape and depth reach old age proportions.

The lowest limit a stream can cut is called base level. It also has temporary base levels determined by such things as dams, levees, and lakes. As the channel of a stream is lowered degradation occurs whereas a channel being built up is one of aggradation.

Deposits made by water form many varieties of rock and can be classified as;

1. Travertine-deposits of calcium carbonate.

2. Calcareous tufa-which is the same as travertine, but more porous.

3. Caliche-ground water, due to dryness, is pulled to the surface by capillary action and calcium carbonate is deposited.

4. Concretions-nodules of mineral material deposited from solution in sedimentary rock.

5. Agate-layers of quartz which are deposited and banded.

6. Geode-the cavities in rock are filled with quartz or calcite crystals.

7. Concentric structures-concretionary deposition around a leaf.

CHAPTER VI

Paleontology

The history of our earth is traced through the rock layers, and fossils found tell us of the life of the past. Fossils are the "living record of the dead" and also tell us of the distribution of lands and seas of pre-historic time. The nature of fossilization falls into two categories,

I. Mineralized

1. permineralization
2. replacement
3. embedding
4. molds, casts, and inprints

II. Non-mineralized

1. refrigeration
2. mummification
3. distillation
4. unaltered

Fossils, to be considered as such must be at least as old as the ice age or Pleistocene. Fossils must also tell something about the organism which it represents. Hard parts commonly are the only parts of an organism preserved.

Geologic time is divided into five eras:

1. Archaeozoic, of which little is known.
2. Proterozoic, or the era of one-celled life.
3. Paleozoic, which is considered the coal era or invertebrate era.
4. Mesozoic, the era of reptiles.

5. Cenozoic, the era of mammals.

Very little is known of the first two eras as there is little fossil record, but beginning with the Paleozoic, the age of our earth is very easily traced through the fossils found in certain periods; Geologic Periods are subdivisions of eras.

The Cambrian period gave birth to trilobites which were the predominant life throughout the period. In the late Cambrian, brachiopods flourished. The Burgess shale, in the vicinity of Lake Louise, is one of the greatest sources for fossils of the Cambrian. Mountain building was very limited and the only plants to appear were algae. During the late Cambrian some uplifting began to take place in Vermont.

The Ordovician period saw the greatest flooding of North America in the whole Paleozoic era. Life was very similar to that of the Cambrian, with the appearance of the cephalapods which were the predominant animal life. During this period in addition to algae, seaweed became the dominant plant life. Near the end of the period the seas withdrew and mountain building was concentrated in the northeastern U. S.

In the Silurian period the first land animals, the scorpions, appeared. Cephalapods were still numerous and the seas were very shallow. The Cincinatti Arch was uplifted and deposits of this period are found in Oklahoma and Texas. The Caledonian Mountains of the British Isles, Ireland, Iceland, and Greenland were formed, and the seas completely withdrew, but the land was not very much above sea level.

The Devonian is often referred to as the 'Age of fishes' and large numbers and varities appeared. The first lung fishes, which were the forerunners of amphibians, first appeared. In the upper Devonian the first amphibians appeared. The Catskill Delta was formed, and a land bridge connecting North America and Europe by way of Iceland, Greenland, Ireland was in existance. Mountain building in the period consisted of a range in New England and Eastern United States.

In the Mississippian the beginning of the Colorado Mountains took place and many deposits of limestone and chert, which is a type of flint, were formed. Predominant animal life of the period was similar to that of the Devonian, however all of the invertebrate phyla were known at this time. Plant life of period began to develop and some large coal supplies were deposited during this period.

The Pennsylvanian saw many more extensive coal deposits formed, and mountain building during this period was fairly prominent. Fossil insects were numerous at this time represented primarily by dragonflies and cockroaches. The first reptiles appeared and there were great swamps formed which disappeared at the end of the period. There were very shallow seas in Central North America.

The last period of the Paleozoic era was the Permian, during which the Appalachian mountains developed. Shallow seas retreated west from Oklahoma and Kansas leaving many deposits of gypsum and dolomite. Animal life was primarily of invertebrate groups, however a few reptiles appeared and some began to walk erect. In the Late Permian period deserts were formed in what is now Arizona and the continents began to emerge throughout the world.

The Mesozoic era is often referred to as the Age of Reptiles and was divided into three periods of time, the Triassic, Jurassic and the Cretaceous.

During the Triassic period, small mammals began to appear. Most of the life of this period is unknown because marine beds are not well exposed and those that are comprise clastic rock which contains very few fossils. There was no crustal uplift and the Appalachian mountains were worn down to smooth hills. Coal swamps developed and petrified forests were formed.

The Jurassic period saw the beginning of the Rocky Mountain geosyncline and deposition was widespread throughout the west central United States. The animal life of the period was divided into two groups as many new forms began to develop.

I. <u>Invertebrates</u>, primarily cephalopods

1. Ammonites
2. Belemnoids which are cigar-shaped, squid like fossils
3. Abundant insects such as butterflies, and moths

II. <u>Vertebrates</u> which were the giant reptiles or dinosaurs

1. Stegosaurus
2. Brontosaurus
3. Tyranosaurus
4. Tricerotops
5. The first frogs, toads, salamanders and birds.

6. Giant reptiles of the sea, the turtles
7. Air reptiles
8. Plants notably Cycads and conifers.

The Cretaceous period saw a great flooding and swamps became numerous, containing clastic deposits. Reptiles still dominated and the mammals were very small though birds became numerous.

The last era of geologic time is the Cenozoic and is that era in which we are now living. It is referred to as the age of mammals. Life of the era is much as we know it today. Bony fishes, alligators, crocodiles were prominent and birds underwent great changes. Grazing animals which were very swift developed into the great complex of horses, cows, sheep, goats, and other mammals known today.

CHAPTER VII

Conclusion

It is the belief of the writer of this report that the science teacher must constantly strive to present new material thus creating a greater interest on the part of the student.

It is his problem, also, to improvise equipment and make use of all available materials. In this report a program is presented that could be useful in the teaching of the earth sciences to ninth grade students. It is necessary, that the person using this outline, have on hand ample rock and mineral samples as it would be impossible to collect all of the specimens mentioned in this report in any one given area.

In presenting the chapter on minerals, and the chapter on rocks, it is hoped that the student will be impressed enough that he will become interested in how these substances came into existence. Through this interest it could be easy to branch out in those fields of geology which deal with the formation of the earth and the life there.

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VITA

James Neil Ogden

Candidate for the Degree of

Master of Science

Thesis: GEOLOGY FOR THE GENERAL SCIENCES

Major Field: Natural Science

Biographical:

Personal Data: Born in Kemp, Oklahoma, April 26, 1922, the son of William L. and Mabel Ogden.

Education: Attended in Snomac, Oklahoma; graduated from Fox High School, Fox, Oklahoma, in 1940; received Bachelor of Science degree from Southeastern State College, Durant, Oklahoma, with a major in Biology, in May, 1948.

Professional Experience: Received an honorable discharge from the United States Army in October 10, 1945; taught General Science, Biology, and Chemistry at Fox, Oklahoma from 1948 to present time.